II.B.15 Separation of Fischer-Tropsch Wax Products from Ultra-Fine Iron Catalysts Particles

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Objectives

- Develop a modular filtration unit for separating precipitated iron catalyst employed in Fischer-Tropsch (FT) synthesis from wax products.
- Correlate the filtration properties of various iron-based catalyst slurries with the chemical and physical changes occurring during activation and FT synthesis.
- Understand the phase changes during activation/reduction and their associated effects on filtration properties.

Introduction

One of the most promising ways for producing liquid hydrocarbon fuels from coal is via coal gasification to synthesis gas (syngas), a mixture of carbon monoxide and hydrogen, followed by FT synthesis to convert the syngas to a mixed product consisting mainly of straight chain hydrocarbons. Syngas (a mixture of H_2 and CO) conversion to liquid fuels and chemicals is of growing importance and of enormous potential for monetizing the large world reserves of natural gas and coal. The FT process has long been used for the production of gasoline from syngas, notably in Germany in WW II and South Africa (SASOL) since 1954, and is probably the most important of all the syngas conversion technologies available today.

The best catalyst system for use in one type of reactor may not be as good for use in a different type of reactor system. For example, until recently, the conventional precipitation methods of preparing iron-based FT catalysts resulted in poor attrition resistance which is important for their use in slurry-phase reactors. Attrition of such catalysts in slurry reactors produces significant amount of fines, making catalyst separation from the products difficult, as the catalysts do not settle well. Although wax filtration systems can be incorporated into the slurry reactor, some problems, such as filter plugging and product contamination by catalyst fines cannot be avoided.

A number of processes have been proposed in the literature to separate heavy wax liquids from catalyst slurries. Most of these techniques can be classified as either internal (filter elements located inside the reactor vessel) or external. Internal methods have the disadvantage of being inaccessible during normal operation of the reactor. Therefore, in anticipation of plugging problems, duplicate filtration systems must be installed to achieve high reliability in commercial settings. The intended design of a cross-flow filter system employs an inertial filter principle that allows the filtrate to flow radially through the porous media at a relatively low face velocity as compared to that of the mainstream slurry in the axial direction. Particles entrained the high velocity axial flow field are prevented from entering the porous media by the ballistic effect of particle inertia. Sub-micron particles penetrating the filter medium form a "dynamic membrane" or sub-micron layer. In many filtration applications, this filtration mechanism is valid for an axial velocity greater than 6 m/s.

Approach

The Center for Applied Energy Research (CAER) has submitted a patent for a modified cross-flow filtration process, developed using a pilot-scale slurry bubble column reactor (SBCR). A preliminary demonstration of this filtration concept and particle attrition measurement technique has been demonstrated by the CAER using a pilot-scale SBCR. The tests were conducted as part of a 3-year DOE-funded project that is currently being completed. The tests showed that the modified filtration technique is effective; however, long-term tests using different catalyst types and FTS conditions need to be investigated. The project will determine this area and also strive to obtain a better understanding of the particle and wax properties in an effort to optimize the design of the filter medium.

Future Directions

- Conduct tests using a variety of precipitated catalyst slurries mixed with various molecular weight waxes (C32, C71, and C100).
- Conduct filtration studies with doping of olefins and alcohols. Filtration studies shall be conducted using a range of olefins varying from 5 to 25 wt% and oxygenates from 3 to 10 wt% to simulate a range of reactor slurries reported in the literature.
- Conduct filtration experiments with ultra-fine iron particles (less than 3 μm) for evaluating the "worst-case" scenario of wax/catalyst separation.
- Chemical and physical characterization of slurry and filtrate.
- Phase II - Bubble Column Pilot Plant Studies (pending government approval after completion of Phase I activities).